Mechanism of High-Temperature Superconductivity

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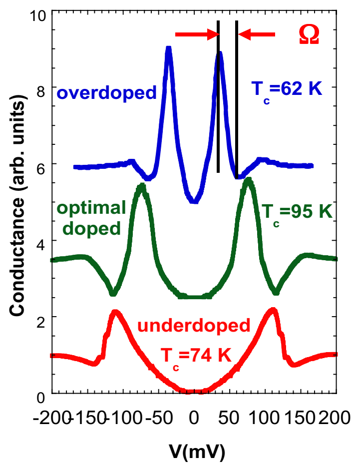
The mechanism of HTS has remained an elusive goal after 15 years and more than 100,000 publications.

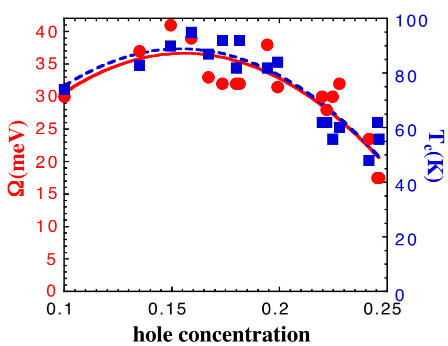
Our tunneling data on BSCCO single crystals provide a strong case for a resolution.

We find a collective excitation energy, Ω, that scales with T_c and has the same magnitude as resonant spin excitation seen by neutron scattering
[H.F. Fong, et al, *Phys. Rev. Lett*. 78, 713 (1997)]

Our data also show an absence of the pseudogap for strongly overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$, contrary to tunneling reports of others, but in agreement with recent ARPES studies [Z. Yusof, et al, *Phys. Rev. Lett*. 88, 167006 (2002)].

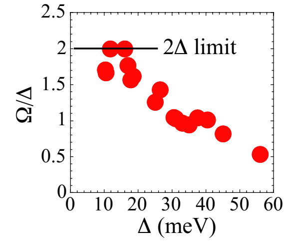


The tunneling spectra for over-, optimally- and under-doped $Bi_2Sr_2CaCu_2O_{8+\delta}$ are similar but exhibit systematic variations of Ω. The sharp coherence peaks define the energy gap at ±2Δ, but Δ does not scale with T_c upon doping. The dip feature with respect to Δ defines the energy of a collective excitation, Ω.

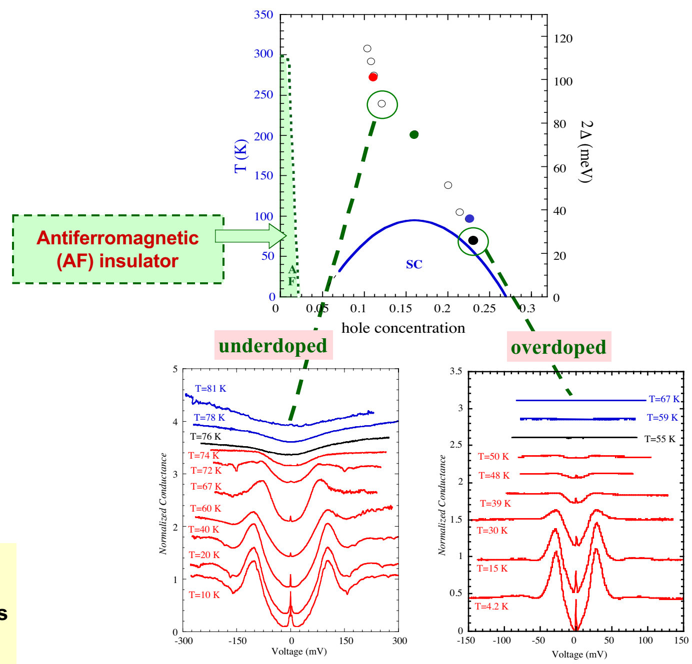


Plots of T_c and Ω versus doping display virtually identical parabolic fits indicating that Ω is proportional to T_c over the entire accessible doping range. The magnitude of Ω and the scaling factor versus T_c are very close to those of the resonance spin-excitation found by neutron scattering.

J.F. Zasadzinski, et al, Phys. Rev. Lett. 87, 067005 (2001)



Any excitation of the electronic system, like the resonance spin-excitation, will be severely damped by pair breaking if the mode energy exceeds 2Δ. We find that Ω is always less than 2Δ, although Ω approaches 2Δ for the most overdoped samples.



While we see evidence of a pseudogap for underdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$, our data on strongly overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ is perfectly flat indicating the strict absence of a pseudogap.

Implications

Our tunneling data, taken with angle-resolved photoemission spectra and theory, present the strongest case yet for resolving the pairing mechanism of HTS, indicating that spin excitations play a crucial role.

For overdoped BSCCO, the absence of a pseudogap and a Δ value close to BCS for a d-wave superconductor suggest a merging of the temperature scales for superconducting pairing and phase coherence. This supports the idea that the pseudogap seen above T_c at lower doping is due to precursor superconductivity.

Future directions

We need significantly underdoped BSCCO to fully understand the pseudogap and how the HTS state merges into the AF insulator.

To establish universality, these effects should be reproduced in another material and some interesting candidates include the highest-T_c Hg-cuprate or La-doped $Bi_2Sr_2CuO_y$ (T_c=25 K).

BES - DOE

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